STS-109 (BI111)
FLIGHT READINESS REVIEW

PROGRAM

February 14, 2002

Solid Rocket Booster

United Space Alliance

AGENDA

Presenter:
Steve Gordon

Organization/Date:
USA-SRB/2-14-02

- Nonconformances
  - Suspect Corrosion on Ethylene Propylene Diene Monomer (EPDM) Covers
- Technical Issues
  - Hydraulic Pump Bolt Torque Preload
  - Auxiliary Power Unit (APU) Controller Diode Failure
  - Suspect Connector
- Readiness Assessment

OUT-OF-FAMILY NONCONFORMANCES

Presenter:
Steve Gordon
Organization/Date:
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Nonconformance

- Suspect corrosion exists beneath rubber and paint on all Ethylene Propylene Diene Monomer (EPDM) covers

Background

- STS-109/BI111 EPDM RH upper strut cover adhesive failed with evidence of corrosion at adhesive bondline
  - Discovered during EPDM strut cover installation in VAB
    - Cover removed and replaced

Worst Case Failure Scenario

- Overheating of SRB to ET critical cables at attach ring/strut interfaces causing loss of TVC and/or separation capability
  - Overheating severity is function of trajectory, time of TPS loss and amount of TPS loss
- Potential debris impact of debonded EPDM on SRB aft BSMs
- Criticality 1 failures

OUT-OF-FAMILY NONCONFORMANCES

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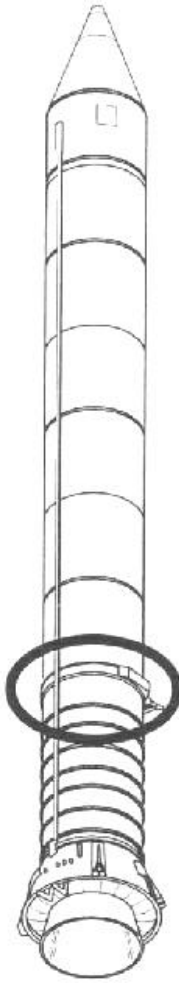
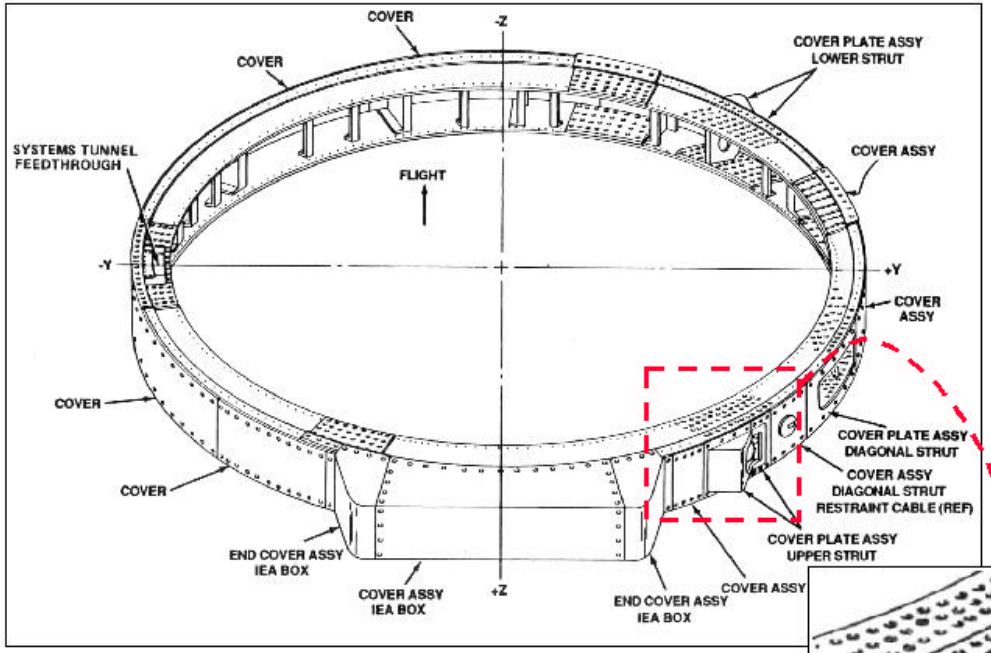
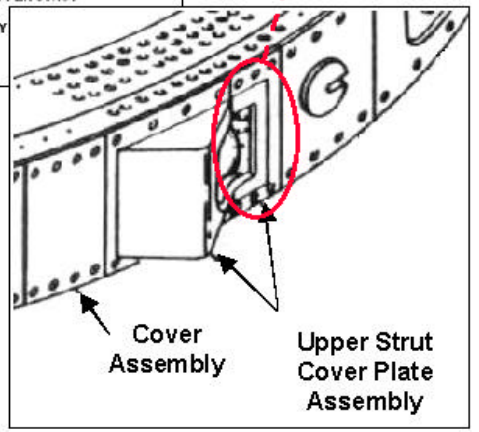




External Tank Attach Ring



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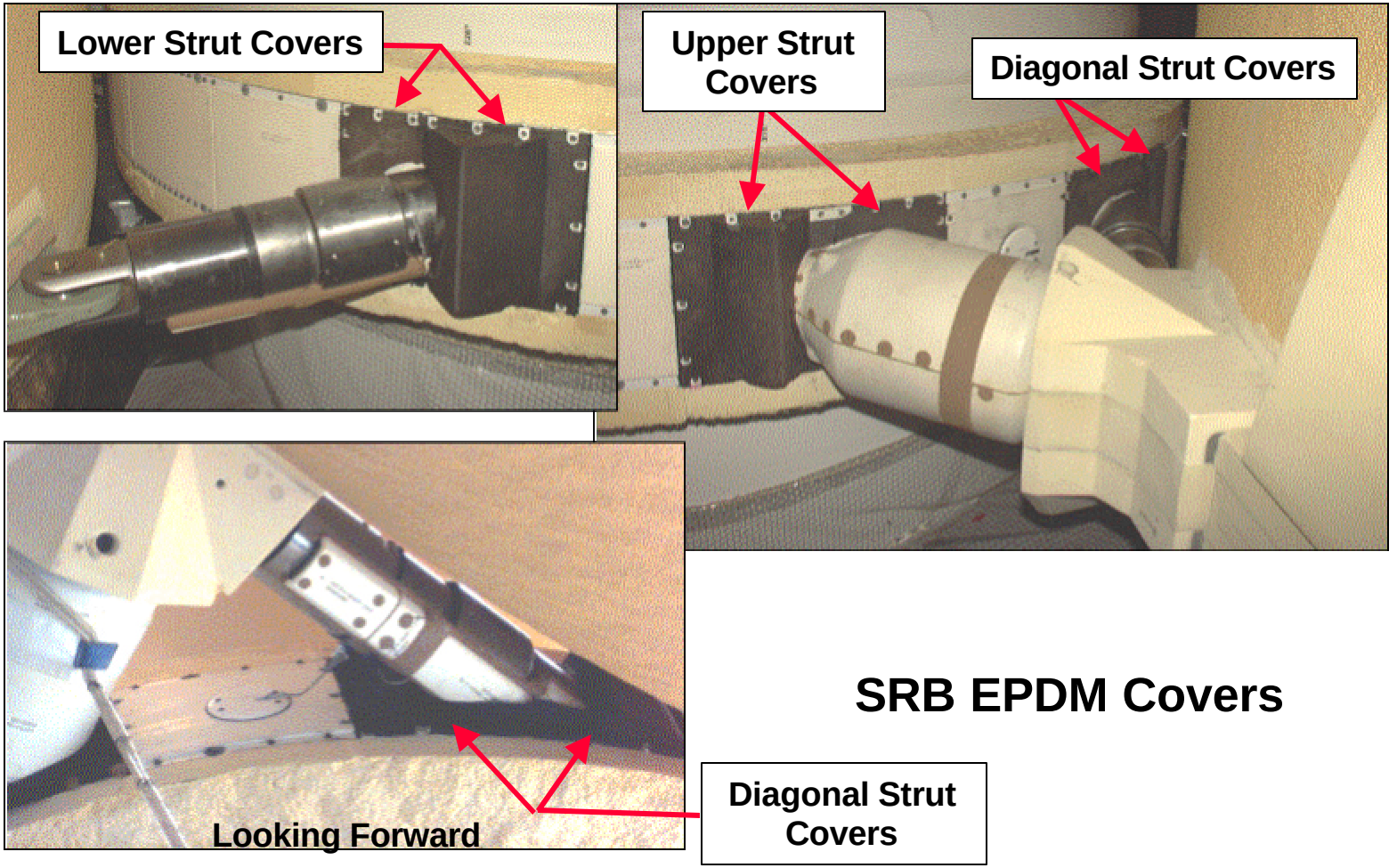

SRB EPDM Covers

OUT-OF-FAMILY NONCONFORMANCES

Presenter:
Steve Gordon
Organization/Date:
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Discussion

- Stock sweep performed on in-stock and flown STS-108 covers
  - Visually inspected all covers
  - Hand applied fold back bond test performed on uninstalled covers
  - Materials testing performed
    - Bond strength
      - One additional in-stock cover failed bondline screen
        - Low bond strength evident over full cover bond
    - Corrosion
      - Maximum depth = 0.001 inches
- All STS-109/BI111 covers inspected in place
  - One additional cover failed inspection
    - Removed and replaced
      - Localized repairable debond

OUT-OF-FAMILY NONCONFORMANCES

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Inspection of SRB EPDM Covers

Installed SRB EPDM Cover - RH Upper Strut

OUT-OF-FAMILY NONCONFORMANCES

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Discussion (cont.)

- Analysis concludes fold back bond test, installation loads and ET/SRB mate loads all sufficient screens for flight load requirements at strut interface
  - Minimum design strengths include 1.4 factor of safety
- Process review and material evaluation in work to isolate specific cause and identify corrective action

Flight Rationale

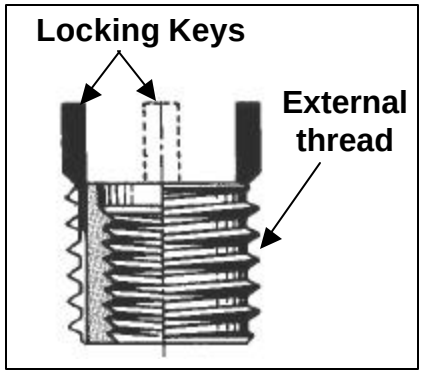
- Inspection of all installed covers reveals no indication of debonds nor visible signs of corrosion
- Two debond failures identified as isolated cases of low bond strength
- Cover installation and ET/SRB mate loads on EPDM rubber screen for sufficient bond strength
- STS-109/BI111 safe to fly with no increase to flight risk

TECHNICAL ISSUE - HYDRAULIC PUMP BOLT TORQUE PRELOAD

Presenter:
Steve Gordon
Organization/Date:
USA-SRB/2-14-02

Observation

- Orbiter Project noted discrepancies in hydraulic pump port cap fastener vendor analyses
  - Calculations utilize high coefficient of friction
  - Questions validity of pump qualification/ certification analysis



Keensert (Typical)

Concern

- Installation torque values (280-300 in.lbs.) could overstress housing threads
  - Keenserts could pull out of aluminum housing

Worst Case Failure Scenario

- Multiple insert failures allow hydraulic pump port cap separation and external release of hydraulic oil, resulting in aft skirt fire and loss of mission, vehicle, and crew
  - Criticality 1

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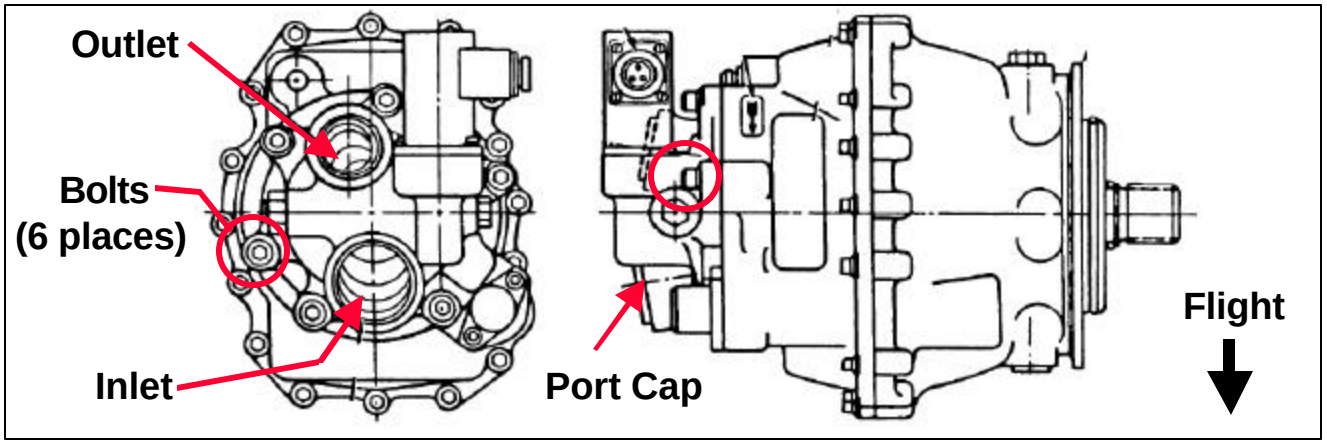
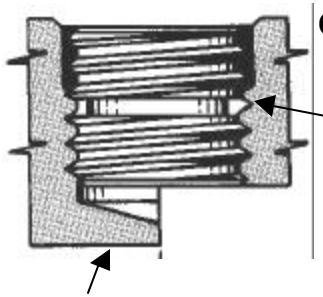
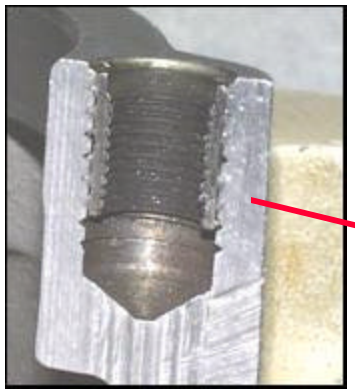
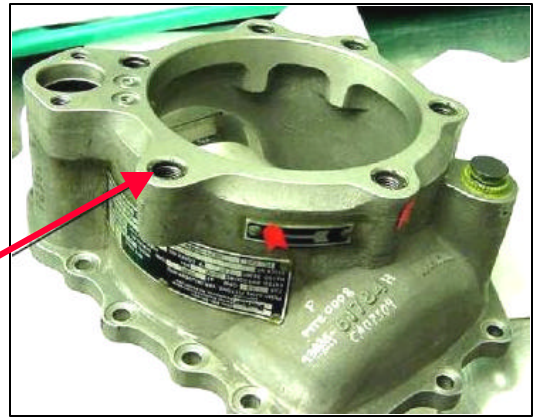


Hydraulic Pump





Keensert (6 places)



Hydraulic Pump Front Housing

United Space Alliance

TECHNICAL ISSUE - HYDRAULIC PUMP BOLT TORQUE PRELOAD

Presenter:
Steve Gordon
Organization/Date:
USA-SRB/2-14-02

Background

- Two design configuration differences between Orbiter and SRB hydraulic pumps
  - Fastener material finish
    - Orbiter design uses passivated bolts without dry film lubricant
    - SRB uses non-passivated bolts with dry film lubricant
  - SRB uses corrosion-inhibiting compound
    - Orbiter bolts installed dry

Discussion

- Port cap/front housing interface utilizes threaded Keenserts to mate with bolts
  - Provides greater strength due to increased shear area
  - Prevents wear on aluminum housing threads

TECHNICAL ISSUE - HYDRAULIC PUMP BOLT TORQUE PRELOAD

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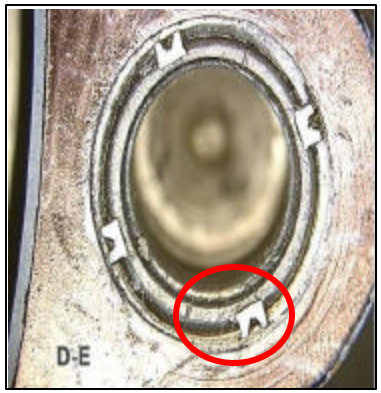
Discussion (cont.)

- SRB pumps refurbished by vendor following every flight
  - Includes visual inspection of threaded Keenserts
    - Occasional Keensert replacement required
      - Replacement results in decreased shear area due to reclocking of locking keys
      - No SRB STS-109 pumps contain replaced Keenserts
  - ATP includes multiple functional checks of suspect joint
    - Proof pressure = 4875 psi (1.5x rated operating pressure)
    - Extensive run time (~8 hrs) with multiple leak checks
  - No indications of pump failure due to housing thread shear
    - Potential incident of stripped threads documented (1999)
      - No evidence of external leakage or performance degradation
- Conservative analysis results in positive margin of safety



Keensert Locking Keys (4 places)

TECHNICAL ISSUE - HYDRAULIC PUMP BOLT TORQUE PRELOAD

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Discussion (cont.)

- Flight representative testing performed at KSC during ACO
  - Multiple leak checks include low/high speed spins and hot fire
- LCC ensures TVC system operation prior to lift-off
  - Hydraulic pump output pressure verified 2800 – 3486 psi
  - Reservoir level verified > 50% following APU start

TECHNICAL ISSUE - HYDRAULIC PUMP BOLT TORQUE PRELOAD

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Rationale for Flight

- SRB pumps refurbished and successfully complete acceptance testing prior to every flight
  - Including proof pressure test
    - Test demonstrates minimum factor of safety of 1.24
- SRB pumps successfully complete ACO testing prior to each flight
  - Including multiple leak checks and hot fire
- LCC ensures satisfactory SRB TVC system performance prior to lift-off
- Analysis indicates positive margin of safety for SRB pumps
- STS-109 is safe to fly

TECHNICAL ISSUE - APU CONTROLLER DIODE FAILURE

Presenter:
Robert Wright
Organization/Date:
USA-SRB/2-14-02

Problem

- Integrated Electronics Assembly (IEA) S/N 025 failed APU BITE test during final acceptance functional test at vendor
  - APU controller Fuel Shutoff Valve (FSV) command alternating between 28 VDC and 0 VDC with BITE frequency applied
- Isolated fault to open Zener diode on APU Controller (APUC) module S/N 158

Worst Case Failure Scenario

- Failure of APUC is Criticality 1R per FMEA/CIL

Background

- Orbiter not affected
- Each IEA contains two controller card modules
  - Primary circuit provides control for Fuel Control Valve (FCV)
    - FCV normally open valve (un-powered)
  - Secondary circuit provides control of FSV
    - FSV normally closed valve (un-powered)

TECHNICAL ISSUE - APU CONTROLLER DIODE FAILURE

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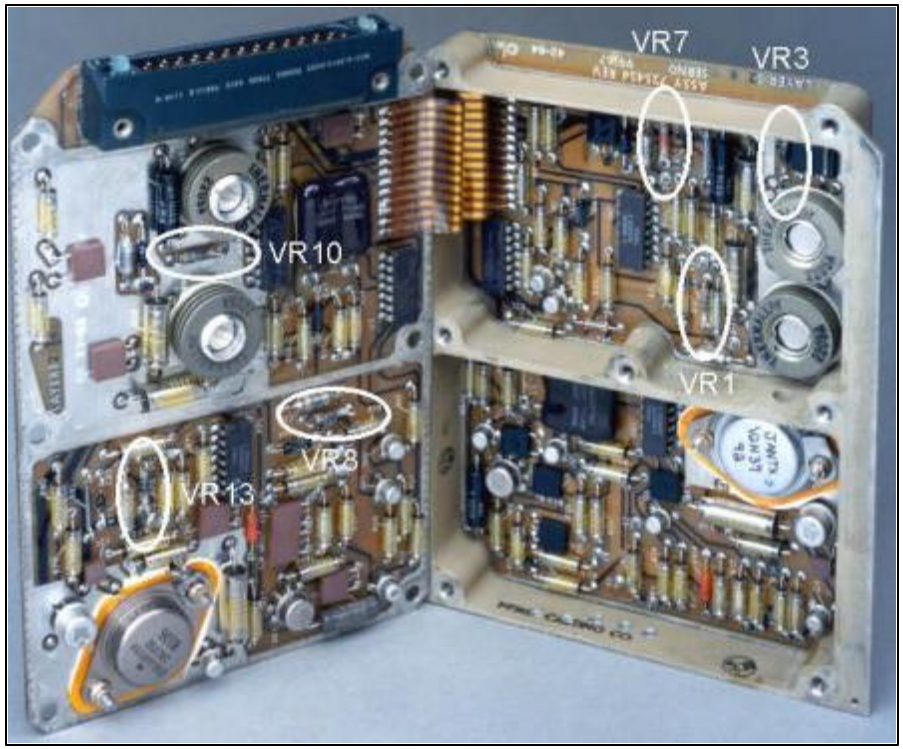
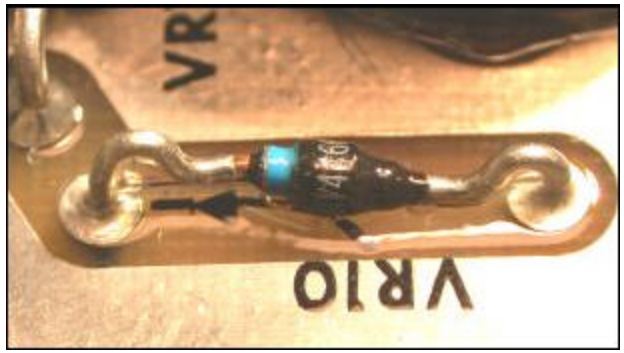
Background (cont.)

- TVC systems operate in 100%, 110% or 112% speed control
  - FSV (secondary) controls speed in 112% - otherwise open



SRB APU Controller Card (Typical)



Failed Diode

TECHNICAL ISSUE - APU CONTROLLER DIODE FAILURE

Presenter:
Robert Wright
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USA-SRB/2-14-02

Discussion

- Failure repeated in IEA and at card level
- X-ray and visual confirm crack in glass body of diode
- Seven previous cracked Zener diode failures of this part type
  - Four failures prior to 1982
    - One detected during module-level testing, three by inspection
  - Three failures from 1982 through 1989
    - Detected by module-level testing
- Diode failure causes identified in previous investigations
  - Stresses in diode from lead bending/installation angle
  - Lack of diode sleeving
  - Urethane conformal coating negating strain relief of diode
    - Printed Wiring Board (PWB) to diode lead and glass body tied together
    - Urethane coefficient of expansion much greater than diode materials
  - Diode body style/package design

TECHNICAL ISSUE - APU CONTROLLER DIODE FAILURE

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Discussion (cont.)

- Six glass-bodied Zener diodes per APU controller module
  - 16 VDC voltage regulator (S/N 158 failure)
    - MSFC testing performed in 1981 concluded no significant degradation to TVC operation in presence of open regulator Zener diode
      - Supported by IEA testing and APUC FMEA
      - USA TVC System modeling with IEA S/N 25 failure condition met all ICD requirements
  - Shutoff transient suppression for FCV and FSV
    - MSFC (1981) and USBI (1990) testing, 150 and 3600 valve transients, showed no degradation to APU controller with open output transient suppression Zener diode
      - Supported by circuit analyses and vendor data
  - Transient suppression on 28 VDC bus power input
    - IEA provides additional 28 VDC suppression circuitry

TECHNICAL ISSUE - APU CONTROLLER DIODE FAILURE

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Discussion (cont.)

- Corrective action planned
  - Rebaseline functionality of APUC diodes (as available)
  - Improve IEA level testing

Rationale for Flight

- All installed aft IEAs hot fired since their previous flight
  - Demonstrates ability of controller to operate TVC system within OMRSD requirements for primary and secondary control modes
- APU BITE performed three times on integrated vehicle prior to launch
  - Injects simulated turbine speeds for 100%, 110% and 112% control points to verify proper response from FSV and FCV
- Circuit design tolerate of diode failures

TECHNICAL ISSUE - SUSPECT CONNECTOR

Presenter:
Robert Wright
Organization/Date:
USA-SRB/2-14-02

Problem

- Upper Strut Cable Failed Pre-installation Continuity Test in VAB
  - Contact fingers out of position
- Inspection of additional cables found second upper strut cable with same condition

Concern

- Potential loss of continuity in flight

Worst Case Failure Scenario

- Loss of Criticality 1R signal/power

Background

- Initial failed cable
  - NAJ6C22-55SC Connector, Lot Date Code (LDC) 9530
  - One flight only

TECHNICAL ISSUE - SUSPECT CONNECTOR

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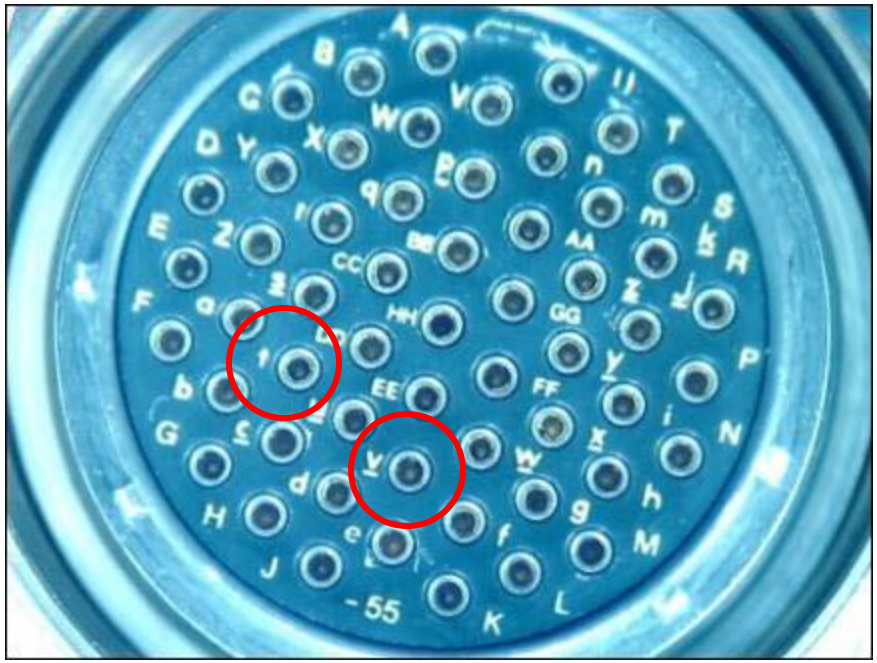
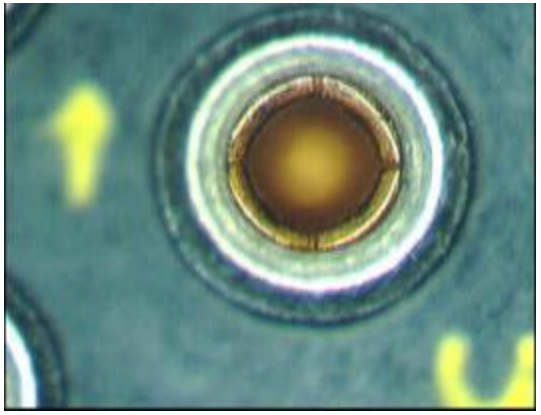
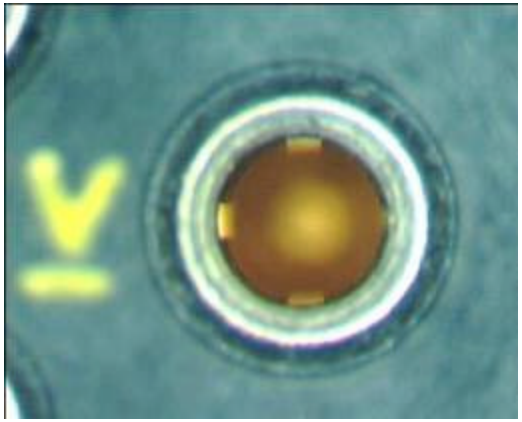


Initial Failed Cable Connector



“t” Socket: Acceptable



“v” Socket: Unacceptable

TECHNICAL ISSUE - SUSPECT CONNECTOR

Presenter:
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Background (cont.)

- Second failed cable
  - NAJ6C22-55SA Connector, LDC 9529
  - One flight only

Actions In Work

- LDC identification for STS-109 cables
- LDC determination for like-cables of entire inventory
- Inspection of additional cables
- Review of industry Alerts for cable type, LDC, manufacturer, similar problem, etc.
- Materials and processing evaluation of failed cable(s)

Rationale for Flight

- In work

READINESS ASSESSMENT

Presenter:
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- Pending successful resolution of technical issues and completion of normal operations flow, there are no constraints to continue launch processing for STS-109

STS-109 (BI111) Flight Readiness Review

Pending satisfactory resolution of technical issues and completion of normal operations flow, we certify the Booster Assembly hardware ready to support the launch of STS-109

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